Dynamic DWDM Control Plane
BRKOPT-2109
Agenda

- **Transport Architecture**
- Control Plane History and Standards
- Wavelength Switched Optical Networks (WSON)
- Optical Control Plane Examples
- End-to-End Control Plane with Packet Optical Transport
- Summary
Next-Generation Transport Architecture

Flexible & Open WDM Architecture:

- **Transparent Transmission**
  - High-performance (EFEC, adv. mod.)
- **Bit-rate & Protocol Independent**
  - ‘Alien-Wavelength’
- **Operations Friendly**
  - G.709 OAMP, tunability, GMPLS
- **Network planning flexibility**
  - ROADM/WXC, 0 Pre-Planning, Planning tools
NG DWDM w/ Optical Control Plane

Realizing the Potential of Intelligence — Tuneability

– Provisioning
– Rearrangement
– Restoration
– Dynamic Bandwidth On-Demand
– Wavelength Switched Optical Network
– Planning Tool Integration and signaling between each NE
– Multilayer Control Plane with IPoDWDM, MPLS-TP and OTN

Expand Network Flexibility
**Next Generation Optical Layer**

**Key Values**
- Complete Control in Software
- No Manual Movement of Fibers
- Increased Service Velocity
- Control Plane Can Automate Provisioning, Restoration, Network Migration, Maintenance

**Foundation for IP + Optical!!**

- **Tunable Laser** – Transmit laser can be provisioned to any frequency in the C-Band.
- **Colorless** – ROADM add ports provisioned in software and rejects any other wavelengths.
- **Tunable Receiver** – Coherent Detection accepts provisioned wavelength and rejects all others.
- **Omni-Directional** – Wavelength can be routed from any Add/Drop port to any direction in software.
- **Restoration** – Ability to reroute a dangling resource to another path after protection switch.
- **Flex Spectrum** – Ability to provision the amount of spectrum allocated to each Wavelength allowing for 400G and 1T bandwidths.
- **Contention-less** – In the same Add/Drop device you can add and drop the same frequency to multiple ports.
What Should an Optical Control Plane Do?

The Key Word is Automatic

Resource Discovery
- Network Elements
- Links
- Link Properties
- Optical Transmission Parameters

Topology Discovery
- Nodes
- Links
- Hypothetical Connectivity Matrix

Traffic Provisioning
- Centralized vs. Distributed
- Pre-computed vs. On-the-fly
- Regeneration support
- Intelligent interworking with client layer

Traffic Restoration
- In cooperation with client layer(s)
- Pre-computed vs. On-the-fly

Network Restoration
- Use of Regens, Multi-Degree nodes

Network Optimization
- Computationally hard

Increasing Complexity
Context for Connection Provisioning

Inventory & Resource Management
1. Neighbor Discovery

2. Global Topology Dissemination

NETWORK
MGMT PLANE

3. Connection Request

4. Path Calculation (NE-based or EMS-based)

5. Signaling Based Connection set up

Dynamic Provisioning
Control Plane

- In simplest form, Control Plane leverages Signaling to automate steps we do manually today.
- Three main models of Control Plane are available:
  1. Peer Model – Optical NEs and Routing NEs are one from the control plane perspective. Routing has full visibility into the optical domain and vice versa.
  2. Overlay Model – Having different Control Planes per layer/Application and having a signaling protocol running between them to make requests
Control Plane

- Provide Multi Layer Support while Respecting Organizational Boundaries
- Leverage Expertise across layers
- Share and leverage information across layers
- iOverlay provides the network knowledge of peering while respecting the boundaries and expertise of each layer
“i” in iOverlay

- “i’ is for information
- What information?
  - L0 SRLGs
  - Latency
  - Path
  - Circuit ID
  - Performance
  - Topology / Feasibility Matrix
- Why
  - Disjoint Circuits
  - Link Bundles
  - Avoid L0 Risk
  - Lowest Optical Cost
  - Coordinated Maintenance
  - Optical Restoration
The Interaction

- Matching / Disjoint / SRLG / Latency Circuit
  - Today:
    - L3 requests circuit of L0 team
    - Ingress and Egress may be different
    - L0 verifies available path
    - L0 verifies performance and resources
    - L0 / L3 Coordinate Circuit Turn up

i Overlay:
- Client Signals circuit request with Disjoint path as other circuit ID
- L0 signals wavelength or path error message
The Interaction

- Restoration – L3 Protect -> L0 Restores

Today:
Protection is provided via L0 Team
1+1, Fiber protection, etc...
Does not efficiently utilize available BW
Increases Cost per Bit

Protection is provided via L3 team
Decrease Interface Utilization based on WC BW
Does not efficiently Utilize BW
Increase Cost per Bit

iOverlay:
L3 detects Circuit degradation and initiates Proactive Protection
L0 Restores capacity back to network and signals existing router port to change if needed.
No SRLG data is propagated and recorded.
A tool to optimize the around entire network
Packet and Optical

Helps reduce unnecessary churn in network

Leverage iOverlay UNI to communicate Topology / Feasibility Matrix
The Interaction

- **Restoration – L3 Protect -> L0 Restores**
  
  Today:
  
  Protection is provided via L0 Team
  
  1+1, Fiber protection, etc...
  
  Does not efficiently utilize available BW
  
  Increases Cost per Bit

  Protection is provided via L3 team
  
  Decrease Interface Utilization based on WC BW
  
  Does not efficiently Utilize BW
  
  Increase Cost per Bit

**iOverlay:**

L3 detects Circuit degradation and initiates **Proactive Protection**

L0 Restores capacity back to network and signals existing router port to change if needed.

No SRLG data is propagated and recorded.
Multilayer Control Plane

- overlay ……
Agenda

- Transport Architecture
- Control Plane Standards
- Wavelength Switched Optical Networks (WSON)
- Optical Control Plane Examples
- Multilayer Control Plane Examples
- End-to-End Control Plane with Packet Optical Transport
- Summar
WSON in the Standards Bodies
(Wavelength Switched Optical Networks)

Charter: Evolution of the Internet (IP) Architecture
(MPLS, MPLS-TP)

Active Participants:
• Service Providers
• Vendors
--WSON,

Charter: Global Telecom Architecture and Standards

Member Organizations:
• Global Service Providers
• PTTs, ILECs, IXCs
• Telecom equipment vendors
• Governments
• ---ASON, impairment parameters G.680

- WSON Optical Impairment Unaware

- WSON Optical Impairment Aware Work Group Document
  http://www.ietf.org/id/draft-ietf-ccamp-wson-impairments-06.txt
Relevant Standards

IETF CCAMP and the ITU-T SG-15 joint liaison leverages existing ITU-T standards work such as G.680 and G.698.x in order to advance the IETF Optical Control Plane work.

- RFC6205 Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers. This defines an appropriate label format when GMPLS controls WSON networks.
- RFC 6163 Framework for GMPLS and Path Computation Element (PCE) Control of Wavelength Switched Optical Networks (WSONs) defines the context, the terminology and architectural options for a GMPLS control plane applied to WSON networks. As in the nature of a framework is an informational document and does not define any protocol extensions.
- draft-ietf-ccamp-rwa-info
- draft-ietf-ccamp-rwa-wson-encode
- draft-ietf-ccamp-general-constraint-encode
- draft-ietf-ccamp-gmpls-general-constraints-ospf-te
- draft-ietf-ccamp-wson-signaling-compatibility-ospf
- draft-ietf-ccamp-wson-signaling
Relevant Standards

The second step defines the WSON with the Optical Impairment awareness. This standardization activity is slightly behind but will be completed once the WSON-RWA will be established. Relevant drafts are:

- draft-ietf-ccamp-wson-impairments A Framework for the Control of Wavelength Switched Optical Networks (WSON) with Impairments. As the previous framework document, this draft defines the scenario for the optical impairment case as well as control plane architectural options. This draft is almost at the end of its path to become RFC.

- Information Model and encoding are still in an early stage and they are individual contribution. The references are:
  - draft-bernstein-wson-impairment-info
  - draft-bernstein-wson-impairment-encode.

- New Draft coming: draft-ietf-ccamp-gmpls-uni-bcp-00.txt on UNI evolutions.
Why We Need WSON

- Automatic network discovery
  - Node, links, network changes
- Automatic A-Z Provisioning
  - Fast Lambda set up, No pre-planned traffic, Bandwidth on demand
- Routing algorithm DWDM Aware
  - Linear (Power, OSNR, CD) and Non-Linear (PMD, FWM, SPM) impairments
- Optical restoration
  - Rapid network re-arrangement, Protection path recovery
  - Network Optimization
- Efficient use of Lambdas
  Minimizes the use of multiple protection lambdas for some Applications (1+R instead of 1+1)
Why Do We Need WSON?

- **WSON is an Impairment aware DWDM control plane (ASON is not)**

- **Client interface registration**
  - Alien wavelength (open network)
  - Transponder (closed network)
  - ITU-T interfaces

- **Wavelength on demand**
  - Bandwidth addition between existing S & D Nodes (CLI)

- **Optical restoration-NOT protection**
  - Automatic Network failure reaction
  - Multiple SLA options (Bronze 0+1, Super Bronze 0+1+R, Platinum 1+1, Super Platinum 1+1+R)
Wavelength Switched Optical Networks Architecture
Agenda

- Transport Architecture
- Control Plane History and Standards
- Wavelength Switched Optical Networks (WSON)
- Optical Control Plane Examples
- End-to-End Control Plane with Packet Optical Transport
- Summary
What Should an Optical Control Plane Do?

Elements of an OCP

- Resource Discovery
  - Network Elements
  - Links
  - Link Properties
  - Optical Transmission Parameters

- Topology Discovery
  - Nodes
  - Links
  - Hypothetical Connectivity Matrix

- Traffic Provisioning
  - Centralized vs. distributed
  - Pre-computed vs. On-the-fly
  - Regeneration support

- Traffic Restoration
  - In cooperation with client layer(s)
  - Pre-computed vs. On-the-fly
  - Regeneration support

- Network Restoration
  - Use of Regens, Multi-Degree nodes

Increasing Complexity
Optical Control Plane for DWDM networks

The Problem

Optical-layer transmission impairments are usually not considered when establishing a light-path in a transparent/translucent optical network.

Optical Channel is assumed to work by design.

Only pre-planned channels are guaranteed to work.

GMPLS (as is) is not sufficient to decide whether a proposed path is feasible in the photonic domain (no Optical Impairment Calculation).

What is concept of optimality in term of Optical Path:

- “Number of Hops”?
- Optical Signal Quality?
- Number of Regenerators?
Why WSON Does not Do for You

WSON is a restoration mechanism rather than a protection mechanism.

Optical Protection guarantees < 50 msec protection and IPo DWDM guarantees < 15 msec protection. Since WSON is a restoration mechanism it does not guarantee sub 50 msec restoration.

Network Planner should plan both protection and restoration together example 1+0+R or 1+1+R

Resolve congested links in the event of fiber cut scenarios
WSON 3 Steps Approach

A Control-Plane extended with optical impairment awareness

3 steps approach towards a full solution:

1. LINEAR Impairments
2. NON-LINEAR Impairments
3. Regeneration Awareness

Optimality Complexity

Approximated Simplified

Optimality Complexity

Approximated Simplified
Optical Parameters in the STDs (G.680)

Many optical parameters can exhibit significant variation over frequencies of interest to the network these may include:

Channel insertion loss deviation (dB, Max)
Channel chromatic dispersion (ps/nm, Max, Min)
Channel uniformity (dB, Max)
Insertion loss (dB, Max, Min)
Channel extinction (dB, Min)
Channel signal-spontaneous noise figure (dB, Max)
Channel gain (dB, Max, Min)
Others TDB in conjunction with ITU-T Q6/15
Non linear impairments are TBD
WSON Should Consider all Necessary Effects

Linear impairments:
- Power Loss
- Chromatic Dispersion (CD)
- Phase Modulation Distortion (PMD)
- Optical Signal to Noise Ratio (OSNR)

Nonlinear Optical impairments:
- Self-Phase Modulation (SPM)
- Cross-Phase Modulation (XPM)
- Four-Wave Mixing (FWM)

Topologies
- Lambda assignment
- Route choices (C-SPF)

Interface Characteristics
- Bit rate
- FEC
- Modulation format

Regenerators capability
WSON Output

- **Automatic Network Discovery**
  Node, Link, Network changes

- **Automatic A-Z Provisioning**
  Fast Lambda set up, No pre-planned traffic, Bandwidth on demand

- **Routing Algorithm DWDM Aware**
  Linear (Power, OSNR) and Non-Linear (CD, PMD, FWM, SPM) impairments management

- **Optical Restoration**
  Rapid network re-arrangement, Protection path recovery
  Network Optimization

- **Extensions to IPoDWDM**
  Router/Switch G.709 Interface Visibility
  Manageability - Virtual Transponder, NLAC, Inventory, Provisioning
OCP Architectural Options

Three different possibilities for the WSON Implementation:

- **CS-OCP**: Centralized Server OCP (PCE Like)
- **CE-OCP**: Centralized Embedded OCP (OSPF Like based)
- **D-OCP**: Distributed OCP (Signaling based)
Distributed-OCP vs Centralized-OCP

- **D-OCP**
  - The network is the database
  - Database is always aligned
  - Advanced protocols and algorithm assure limited convergency time
  - SCN relies on the network
  - No requirement on OOB DCN

- **C-OCP**
  - Database must be kept aligned, alignment may require long time
  - DCN becomes “business critical”, it becomes SCN
  - Centralized server becomes “business critical”
  - Existing DCN and Servers are not suited for C-OCP. SP must change everything
Agenda

- Transport Architecture
- Control Plane History and Standards
- Wavelength Switched Optical Networks (WSON)
- Optical Control Plane Examples
- End-to-End Control Plane with Packet Optical Transport
- Summary
Sample Network

Nodes:
- OXC 4 degrees nodes

Links:
- 60 Km TWC Fibers (2 unidirectional fibers)
- 4 BandC wavelength (193.2 (1) - 193.5 (4) GHz, 100GHz spacing)
- Pre-Ampli at +1.0 dBm nominal output power
- Bst-Ampli at +1.0 dBm nominal output power
- DCUs: SMR 100 ps/nm on links 1-2 and 21-2

Service Requests:
- 10 Gbps unidirectional channels through ClassP Transponders
LSP 1 Setup: OXC 1 -> OXC 8

Egress Channel Eval:
- Channel Optical Feasibility
  - all channels feasible
- WL/Transponder Assign:
  - WL 1 selected

Channel Setup
- In/Out XC (WL 1)
- Store LSP Optical Params:
  - Margin Xtalk
  - Section Residual CD
  - Section Reference FWM
  - Signal/Transponder Type
Agenda

- Transport Architecture
- Control Plane History and Standards
- Wavelength Switched Optical Networks (WSON)
- Optical Control Plane Examples
- End-to-End Control Plane with Packet Optical Transport
- Summary
Network Architecture

Any Transport over DWDM
Control Plane Multi-Layer Interaction

- **WSON**: Wavelength switched optical network
- **ASON**: Automatically Switched optical network
- **ASMN**: Automatically switched MPLS-TP network

- Legacy Traffic
- Wholesale
- IP Core
- Carrier Ethernet
- NGN

- OTN / TDM
- NG-ASON
- IP / MPLS
- S-GMPLS

- MPLS-TP
- ASMN

- Wavelength on demand
- Optical restoration (1+R, 1+1+R)
Network Layer Architecture

- Agile DWDM
- Zero touch ROADM
- Photonic latency less bypass

Access and aggregation:
- MPLS-TP PW

Aggregation – core:
- Packet Transport Switch
- MPLS-TP / MPLS

Access and aggregation:
- MPLS-TP PW

Access service delivery

POTS Intelligent networking with MPLS-TP and IPoDWDM interfaces

L0 intelligent DWDM

Packet Transport Convergent network

Aggregation

Service Focus

Corporation

Residential
Towards Dynamic Service Activation

**Manual Patching and pre-planning**
- Manual provisioning of each node
- Manual patching of each node
- High OpEx
- Truck rolls to every node

*With ROADMs and WXC and pre-planning*
- Manual provisioning via NMS
- Auto-patching via intermediate ROADMs and WXC
- Lower OpEx
- More service flexibility
- Truck rolls to end points

**Dynamic Service Activation – No pre-planning**
- With colorless, omnidirectionality, tunability
- Auto provisioning wavelength on demand
- via S-GMPLS
- Auto patching via ROADMs and WXC
- Lower OpEx even further
- No truck rolls
- Works w/ SR+TXP and/or IPoDWDM
IP/MPLS Benefits with WSON Control Plane

- Add/Remove Bandwidth on demand on the same link
- 1+1+R Restoration capability
  - Back to line rate
  - Freeing up old working connection
  - Flexibility to multiple failure
- Shared Risk link group (S-GMPLS)
- Network optimization (along the time!)
  - Move wavelengths to re-adjust bandwidth
  - Keep the links
WSON Functionality

- Impairment aware control plane
- Client interface registration
  - Alien wavelength (open network)
  - Transponder (closed network)
  - ITU-T interfaces (segmented network)
- Wavelength on demand (zero planning wavelength setup)
  - Bandwidth addition on the same connection
  - New connection setup
  - Wavelength reroute for latency reduction
- Optical shared restoration (0+1+R and 1+1+R)
  - Network failure reaction
  - 2nd failure handling
  - Multiple SLA options (Bronze 0+1, Super Bronze 0+1+R, Platinum 1+1, Super Platinum 1+1+R)
Bandwidth on Demand

At a certain time bandwidth required between A and B exceeds the available one.

The router A has 4xNGB connection to B. It asks for N+1.
Either The control plane allocates a new lambda between the 2 sites over an existing path.
Bandwidth on Demand

Or The control plane allocates a new lambda between the 2 sites over a new path
Rapid Service Setup

Transponder spare cabled at A and B

Client to ODF

Trunk to Color Less / Omni directional DWDM system
Rapid Service Setup

WSON Control plane find a valid path A to B and set up the wavelength
Rapid Service Setup

WSON Control plane color the Transponder trunk to match the wavelength
The connection is up! The customer can use it
Rapid Service Setup

The SP re-stock the spare Transponders at both site A and B.
Unprotected Lambda Group
0+1+R

Failure detected and propagated thru G.798 network level alarm correlation
Lambda group rolled to a new path. Re-colouring possible.
0+1+R

Freeing up old path
1+1 Lambda protection method (e.g. Y-Cable, mesh lambda protection)
1+1+R

Failure happens
Create new 2x Lambda connection using different path
Free up resources of the old one
Change Source / Destination

Starting from 2 lambdas between A and B
Change Source / Destination

Moving 1 lambda from C to B
MultiLayer Control Plane
Agenda

- Transport Architecture
- Control Plane History and Standards
- Wavelength Switched Optical Networks (WSON)
- Optical Control Plane Examples
- End-to-End Control Plane with IPoDWDM
- Summary
WSON Requirement & Enabler: Full Flexibility & Switching @ DWDM Layer

Remotely re-configure wavelengths in any Color and any Direction on ALL Nodes without re-wiring ANY fiber.
Rapidly reconfigure bandwidth
Capitalize on changes in network demand and transitory events

**Tunability**
Wavelength is a routing element and can be SW Provisioned and Changed remotely

**Omni-Directional**
Decouple Add/Drop entry point from the Line direction facing the Network

**Colorless**
Decouple the Add/Drop port from the wavelength to allow SW Provisioning and Protection

**Contentionless**
Expand Add/Drop capacity for an ROADM Node w/o restricting the re-usage of the same wavelength

**DWDM-Aware CP**
Fully automated End-to-End SW provisioning taking into account DWDM specific parameters

Touchless DWDM Solution
Intelligent Control Plane Business Benefit

- Simplified WDM provisioning
  - Routing decisions made by network
  - Fewer, less complex planning designs
  - More accurate and reliable provisioning process (Network as the Database)
  - Bandwidth Efficiency

- Automated Engineering and planning for optical routing and path set up
  - Dynamic Wavelength Routing
  - Wavelength reach verification
  - Optimize regenerator use
  - Auto discovery of network changes

“Keep operational costs steady as the network grows”
Applications

- Wholesale restorable wavelengths
  - 0+1+R (Super Bronze)
  - 1+1+R (Super Platinum)
- Wavelength rerouting
  - Change source / Change destination
- Rapid service setup
Demonstration of Optical Control Plane

- Gianluca Calabretta
- Dianne Patton – discuss re CLI driven bandwidth provisioning
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASON</td>
<td>Automatically Switched Optical Network</td>
</tr>
<tr>
<td>AToDWDM</td>
<td>Any Transport over DWDM</td>
</tr>
<tr>
<td>CCAMP</td>
<td>Common Control and Measurement Plane</td>
</tr>
<tr>
<td>DCU</td>
<td>Dispersion Compensation Unit</td>
</tr>
<tr>
<td>EFEC</td>
<td>Enhanced Forward error Correction</td>
</tr>
<tr>
<td>GMPLS</td>
<td>Generalized Multiprotocol Label Switching</td>
</tr>
<tr>
<td>IPoDWDM</td>
<td>IP over DWDM</td>
</tr>
<tr>
<td>ITU Q6/SG 15</td>
<td>ITU Question 6 Study Group 15</td>
</tr>
<tr>
<td>MPLS-TP</td>
<td>Multi Protocol Label Switching - Transport Profile</td>
</tr>
<tr>
<td>NE</td>
<td>Network Element</td>
</tr>
<tr>
<td>OAMP</td>
<td>Operation Administration Maintenance and Provisioning</td>
</tr>
<tr>
<td>OTN</td>
<td>Optical Transport Network</td>
</tr>
<tr>
<td>RFC</td>
<td>Request for Comments</td>
</tr>
<tr>
<td>UNI</td>
<td>User Network Interface</td>
</tr>
<tr>
<td>WSON</td>
<td>Wavelength Switched Optical Networks</td>
</tr>
<tr>
<td>WXC</td>
<td>Wavelength Cross Connect</td>
</tr>
</tbody>
</table>
Complete Your Online Session Evaluation

- Give us your feedback and you could win fabulous prizes. Winners announced daily.
- Receive 20 Passport points for each session evaluation you complete.
- Complete your session evaluation online now (open a browser through our wireless network to access our portal) or visit one of the Internet stations throughout the Convention Center.

Don’t forget to activate your Cisco Live Virtual account for access to all session material, communities, and on-demand and live activities throughout the year. Activate your account at the Cisco booth in the World of Solutions or visit www.ciscolive.com.
Segue Slide